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The United States Digital Recording Industry

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The recording industry resembles the semiconductor industry in several aspects. Both are large (>\$60 Billion/year revenues); both are considered critical technologies supporting national objectives; both are experiencing increased competition from foreign suppliers; they recognize significant opportunities for both technological and market growth in the decade to come; and both realize that a key to this future growth lies in alliances among industry, academia, and government.

The semiconductor industry has made significant investments in alliances relating to manufacturing technologies (SEMATECH) and to joint long-term technology research centered in universities (SRC). The federal government has provided funding support of these efforts in recognition of the critical roles semiconductor technologies play in national interests.

The recording industry is now also forming critical alliances, but has been slower in starting and in gaining broad recognition by government agencies and legislators that the industry needs federal support. Traditionally, the recording industry has been viewed as mature, stable, and, while critical to national interests, able to chart and fund its own course toward future national needs. That perception is fortunately changing.

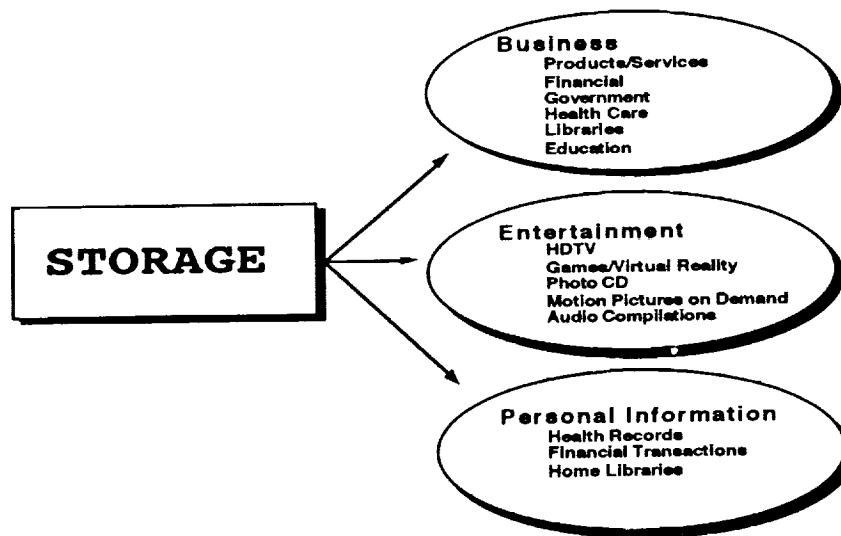
Industry Challenges

In fact, the recording industry faces unprecedented challenges. Foreign companies play a dominant role in all aspects of consumer recording and in the supply of components and in manufacturing for other recording products. At the same time, U.S. recording industry profits have eroded (or gone negative), forcing personnel downsizing and even corporate failures. Manufactured quantities of hard disk drive units have been growing at a compound annual growth rate (CAGR) of 14%. In terms of recording capacities, the total aggregated storage capacity of the hard drives shipped is increasing at a CAGR of 44%. The result of all this is a current oversupply of disk drives, driving profits of some companies to new lows. Even if U.S. corporations can survive these problems, economic pressures have made it increasingly difficult to make long-term investments in research.

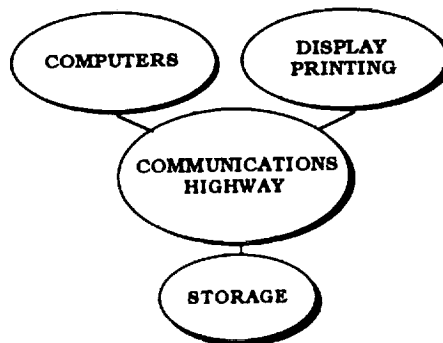
Opportunities for Growth

On the positive side, the long-term market growth potential for recording is significant, assuming that the industry can survive the current problems.

The figure below depicts three main market growth vectors for recording: (1) expanding business, education, health, and governmental markets; (2) increased opportunities for recording in entertainment services (driven largely by HDTV); and, (3) a potential for a large growth in personal information systems.



These opportunities are consistent with the vision for the National Information Infrastructure that has been widely discussed by a variety of governmental sources. This concept involves a central communications highway which is fed by high-performance systems of computers, software architectures, displays/printers, and, of course, digital storage.



Combined, these opportunities for growth could result in a market size for recording within the next ten years which is more than an order of magnitude greater than at present. In fact, one executive of a large U.S. company speculated on a market size approaching a trillion dollars per year in that same time frame. The challenge for the recording industry is to build these future markets by developing systems solutions for the new storage-intensive applications.

Foreign corporate strategies clearly have targeted the growth opportunities in the entertainment and consumer segments, with the ancillary expectation that the resulting technology and manufacturing capabilities will feed product offerings in the commercial and governmental sectors. Further, foreign governmental support of the requisite alliances to make this all happen is both strong and mature.

Corporate planners in this country are no less perceptive of the opportunities, but they have traditionally experienced barriers to form the same level of alliances toward focused objectives. First, it was once common for the U.S. government to resist corporate alliances for anti-trust reasons. Fortunately, that situation has been significantly improved in recent years. Second, our litigious society raises barriers for organizations to work together¹. Third, there is an inherent distrust among some organizations to work with each other. We come from

¹The author can be induced with almost no urging to relate his harrowing experiences in trying to get corporate and university lawyers to agree on intellectual property agreements, for instance.

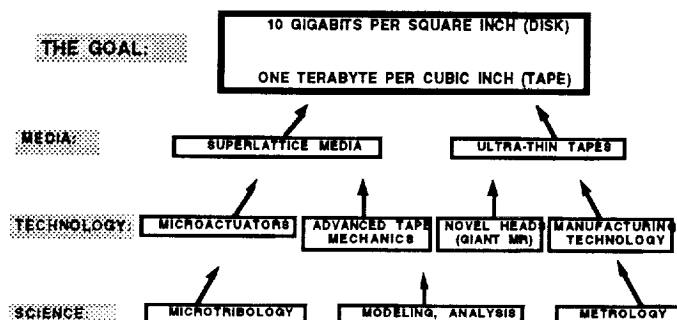
a history of each company acting independently toward market development and penetration. And fourth, our federal and state governments are still seeking the most effective ways to provide support for critical industry segments.

Alliances

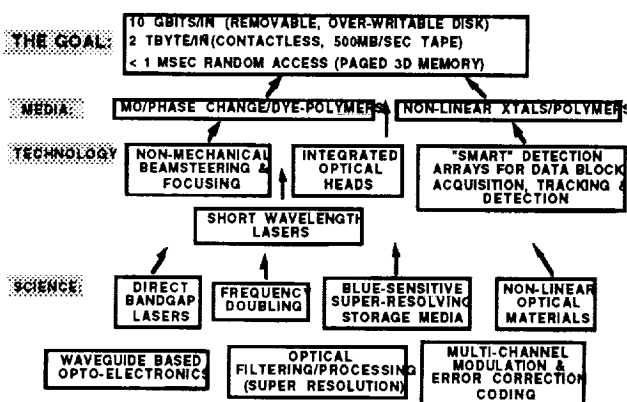
Like the semiconductor industry, the U.S. recording industry is taking steps to work together toward the opportunities that are commonly perceived. The National Media Laboratory, based in Minneapolis, is an effective organization which addresses government users and their needs for systems support and testing. More recently, the National Storage Industry Consortium (NSIC) has been formed² with the objective of enhancing the competitiveness of the U.S. recording industry through a strategic plan to form joint research programs on pre-competitive technologies and to coordinate technology developments among corporations, universities, and governmental organizations.

NSIC today has 36 member companies and over 30 universities which support the ongoing joint research programs that have been established. Early in its development, NSIC held workshops to prepare technology roadmaps for the storage industry. The following two figures summarize elements of NSIC's strategic plan for hardware and media technology developments; this plan is now being updated in detail and is being augmented by programs in software systems and in manufacturing technologies.

MAGNETIC RECORDING - 21ST CENTURY



OPTICAL RECORDING - 21ST CENTURY



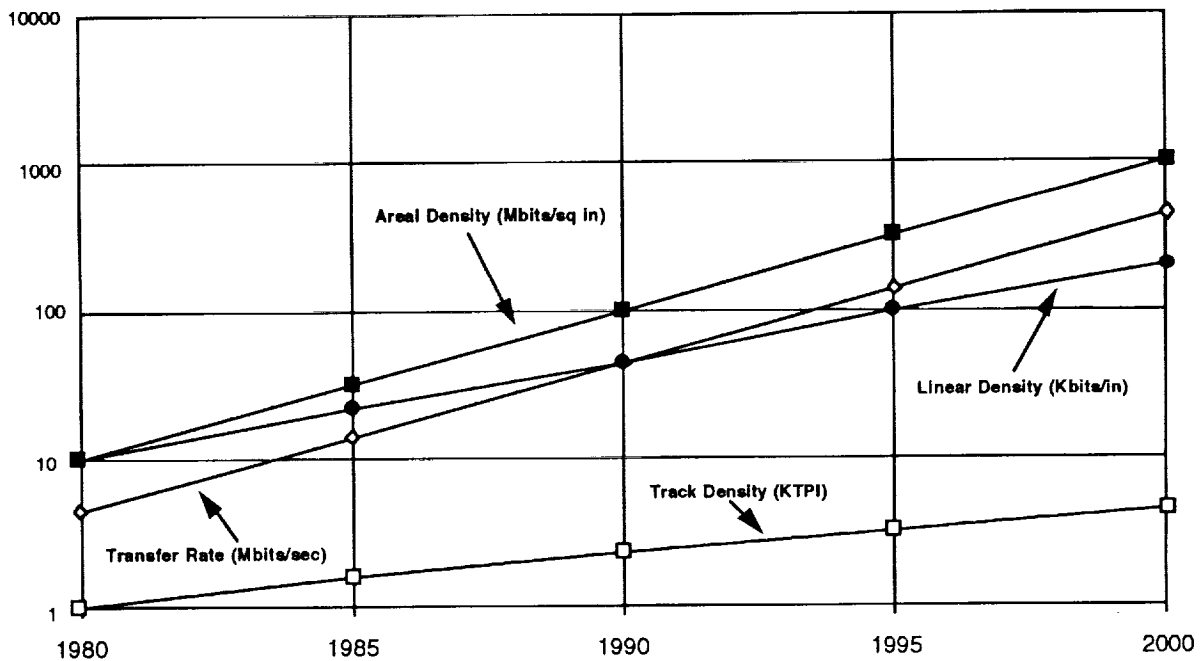
²Incorporated in California, April, 1991

CURRENT NSIC JOINT RESEARCH PROGRAMS

On the basis of this early work, members of NSIC proposed key joint technology research programs which have subsequently been established and which are currently partially funded by both NIST/ATP and ARPA. The goal of these programs has been to create pre-competitive technologies which will enable magnetic disk recording at 10 Gigabits/in², magnetic tape recording at one Terabyte per cubic inch, and optical recording at 10 Gigabits/in².

The figure below depicts a number of recording system performance parameters as a function of time. Our industry has traditionally produced technology advances which, for most of the

RECORDING SYSTEMS PERFORMANCE



important performance parameters, plot linearly on the semi-log scale shown. These linear plots indicate, for instance, that, by the year 2000, the industry would be expected to provide products with areal densities of one Gigabit per square inch and track densities of less than 10,000 tracks per inch.

The NSIC goals postulate performance well beyond the usual industry trajectories in each of the parameters shown. By setting targets well beyond normal industry expectations, we encourage non-evolutionary approaches to technology development. To illustrate this point, current NSIC programs have goals for areal densities of 10 Gigabits per square inch and track densities (for magnetic disks) around 25,000 tracks per inch. Reference to the figure above shows that these targets are significantly beyond the progress that would traditionally have been expected within this industry.

The table on the following page is a financial summary of four present major NSIC joint research programs. All data are expressed as \$K.

NSIC 5-YEAR JOINT RESEARCH PROGRAMS

PROGRAM	FUNDING AGENCY	FEDERAL FUNDING	NSIC FUNDING	TOTAL COSTS
SWAT (Start: 5/91) Years 1 - 5	ATP/NIST	\$5,421	\$8,862	\$14,283
HEADS (Start: 8/92) Years 1 - 5	ATP/NIST	\$5,534	\$6,246	\$11,780
UHD RECORDING (Start: 3/93) Years 1 - 2	ARPA	\$10,700	\$11,633	\$22,333
Years 3 - 5	NOT YET IDENTIFIED	\$17,335	\$20,360	\$37,695
HOLOGRAPHIC RECORDING MATERIALS Years 1 - 3	ARPA	\$6,272	\$6,272	\$12,545
TOTAL ALL PROGRAMS		\$45,262	\$53,373	\$98,635

The first program (SWAT - funded by NIST/ATP) is aimed at producing short wavelength sources for optical recording. The approach is to use nonlinear optical materials to effect frequency doubling of red diode lasers to produce blue integrated sources with an attendant reduction in mark sizes on optical media. The second ATP-funded program addresses new magnetic heads technology to meet the high-density goals set forth above. The third program on the list is a large ARPA-funded program with a variety of technical objectives in both optical and magnetic recording. The fourth program (PRISM - also ARPA funded) is aimed at development of holographic recording materials which will be stable and which can be manufactured reliably at low cost. Figure 5 substantiates that this industry and its government sponsors are seriously committed to using this process of joint research for advanced technology developments in this critical industry.

Still other NSIC programs are in the proposal stage. A 5-year program leading to digital optical tape recording capable of providing several Terabytes of data in a small cartridge (similar to a 3480 cartridge) has been proposed to ARPA as a TRP proposal. Another proposal is being put together relating to the development of prototype holographic data recorder systems which utilize the materials being developed in the PRISM Project. Yet another in process is a program addressing manufacturing technologies for the recording industry.

SOFTWARE, SOFTWARE ARCHITECTURES

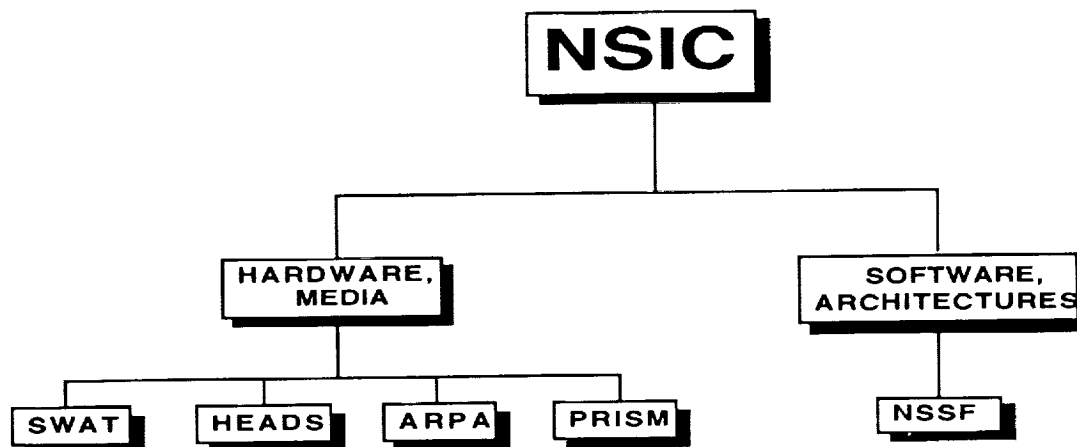
NSIC to date has focused on hardware and materials aspects of optical and magnetic recording. We recognize that there is an equally critical need for development of software relating to mass storage systems. Quoting from pending legislation:

"NASA, ARPA, NSF and appropriate agencies shall develop technologies for "digital libraries" of electronic information. Development of digital libraries shall include development of advanced data storage systems capable of storing petabytes of data and giving thousands of users nearly simultaneous access,development of database software capable of quickly

searching, filtering, and summarizing large volumes of text, imagery, data, and sound,development and adoption of standards for electronic data,technology for simplifying the utilization of networked databases distributed around the nation and around the world."

These software developments are essential from two points of view: (1) they are necessary if we are to take advantage of the significant gains expected in the performance of recording technologies, and (2) achieving the goals of the National Information Infrastructure (NII) demands that these capabilities exist to enable efficient database sharing throughout the network.

For these reasons, NSIC, working with the National Storage Laboratory at Lawrence Livermore National Laboratory and other industry software developers, has recently formed a new division of NSIC, the National Storage System Foundation (NSSF).



This division, like the earlier NSIC structure, will have membership from NSIC industrial companies, universities, and the national laboratories. It is intended to augment and extend existing collaborations and standards organizations in standardizing, developing, and transferring technology for high performance storage systems.

The objectives of NSIC/NSSF are to:

- Create a United States digital library strategy
- Develop core technology for high capacity, high performance digital libraries and storage systems
- Develop technology for simplifying access to digital libraries
- Define a coherent storage system infrastructure
- Establish requirements for buildable components
- Promote interoperability among components from different developers
- Encourage the development and adoption of standards
- Organize and seek funding for collaborative research projects for next generation digital libraries and storage systems

The establishment of NSSF will encourage, through NSIC's central coordination, interactions between the software and hardware communities. Hopefully, both divisions of NSIC will influence and enhance each other's offerings in designing approaches to the needs of NII.

So, what's next?

NSIC is presently sponsoring a detailed process of producing an updated and detailed technology roadmap for this industry - both software and hardware components. Participating in this process are industry, university, and national laboratories persons. Government persons are also invited to participate (any who would like to join are asked to call the author). In addition, a comprehensive National Plan for the recording industry is being prepared. This plan will describe the recording industry and its several segments in terms of both business issues and technology needs for future development. It will make use of the technology roadmap referred to above. It will conclude with a set of recommendations for government action in support of this industry.

At this time, it is premature to review the specific recommendations which will be made for government action. It's safe to say that these will include a request to assist this industry by a process that starts with a committed federal budget amount for investments in support of this industry. This budget would be used to fund new joint research programs, university or national laboratories work, or other activities which are judged to be important to NSIC's mission of enhancing the competitiveness of the U.S. recording industry.

